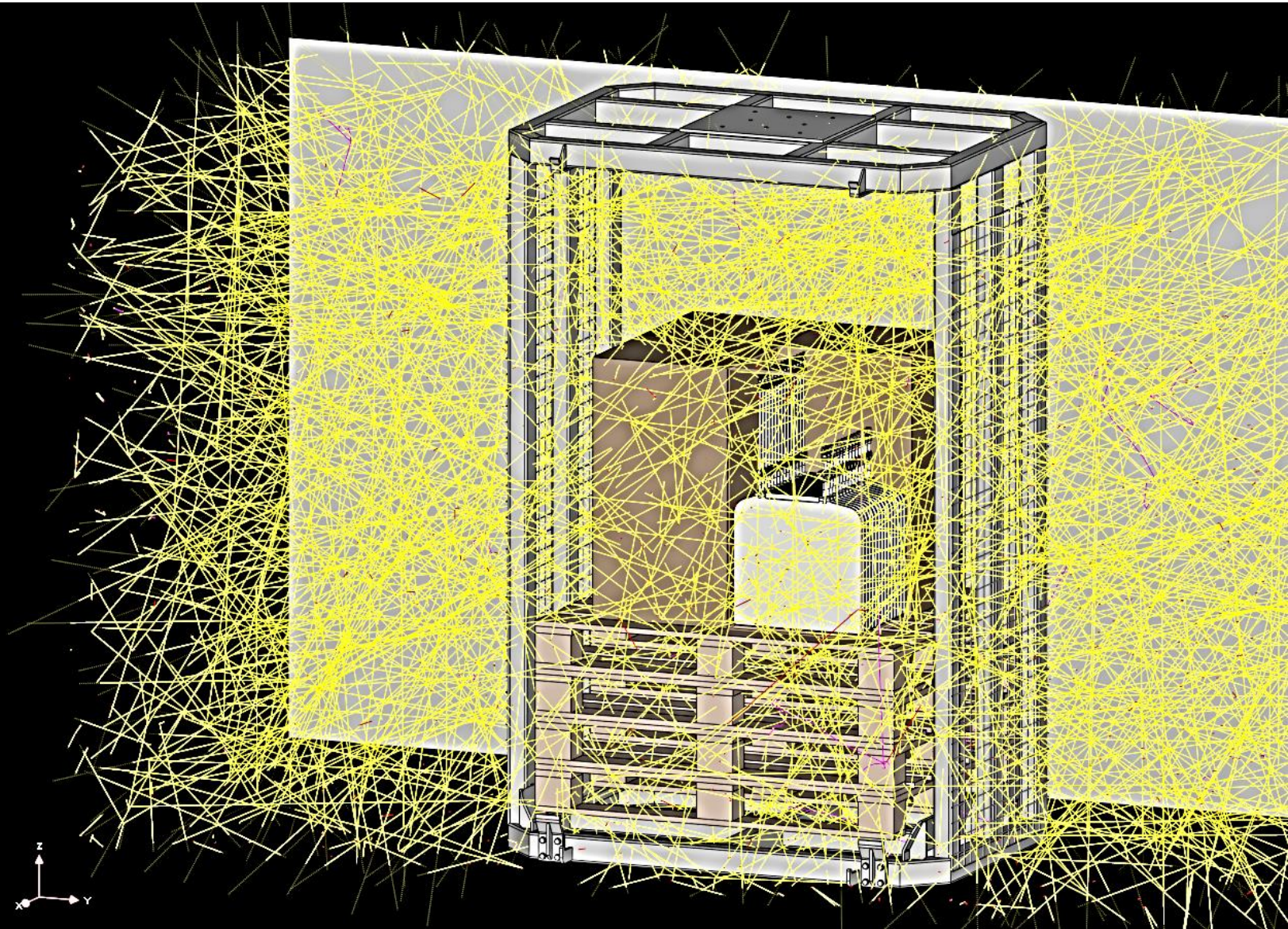
XRAY IRRADIATION PROCESS SIMULATION

TRAD Tests & radiations

WITH *RAYXPERT®*



Ludovic EYCHENNE
Antoine GHILARDI

22nd of September

*is a software developed by **TRAD Tests & Radiations** since 2012 that associates a **3D modeling** tool to a **Monte Carlo** calculation method to perform radiation simulation and dose rate calculation for the **Industry**, the **Nuclear** & **Medical fields***

Electron & Positron | Gamma & Xray | Neutron

Industrial process

- OQ & PQ
- Product and Packaging design
- Source optimisation
- Tranfer from Gamma/ETO to Xray/Ebeam

- Non destructive inspection
- Mining extraction & purification

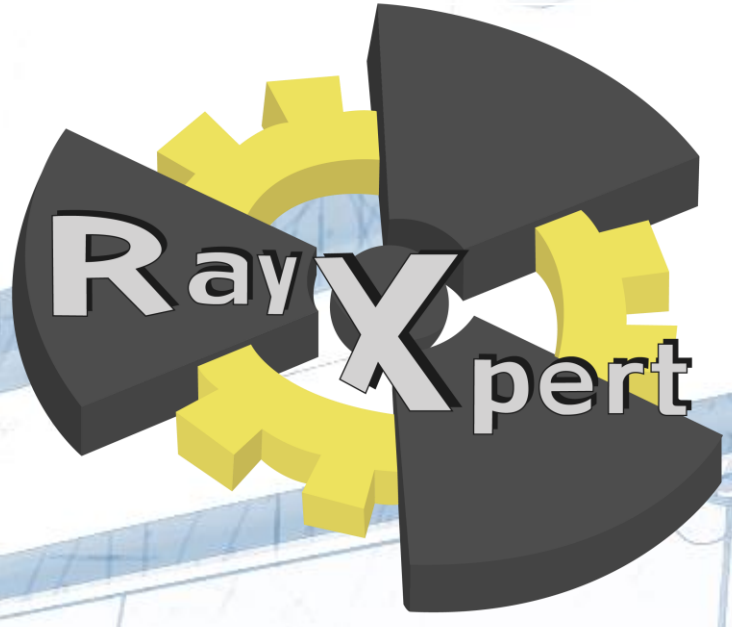
Radioprotection

- Xray and Ebeam equipment design
- Bunker design – new built and evolution

- Transport study
- Buidling & Storage room design
- Dismantling & Waste Management

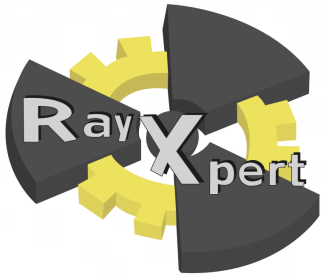
CONTEXT OF THE STUDY

How can Monte Carlo codes be used to optimize the number and location of dosimeters during an industrial medical irradiation process?



CONTEXT OF THE STUDY

Dosimetry optimization of an Xray irradiation process on a Medical Device



3D MODELING	Use **CAD import** associated to modeling tools to define 3D model
SOURCE DEFINITION	Define the beam shape, trajectory and spectrum
3D MAPPING	Perform the irradiation process on the products and calculate a 3D mapping to locate the **minimum** and **maximum** dose areas
VIRTUAL DOSIMETERS	Perform the irradiation process with dosimeters located on the specified areas
ANALYSIS & OPTIMIZATION	Dose distribution analysis regarding to different configuration of the product to find the most efficient way to proceed

3D MODELING

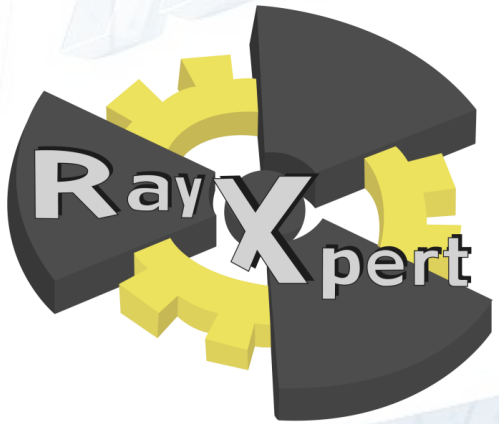
SOURCE DEFINITION

3D MAPPING

VIRTUAL DOSIMETERS

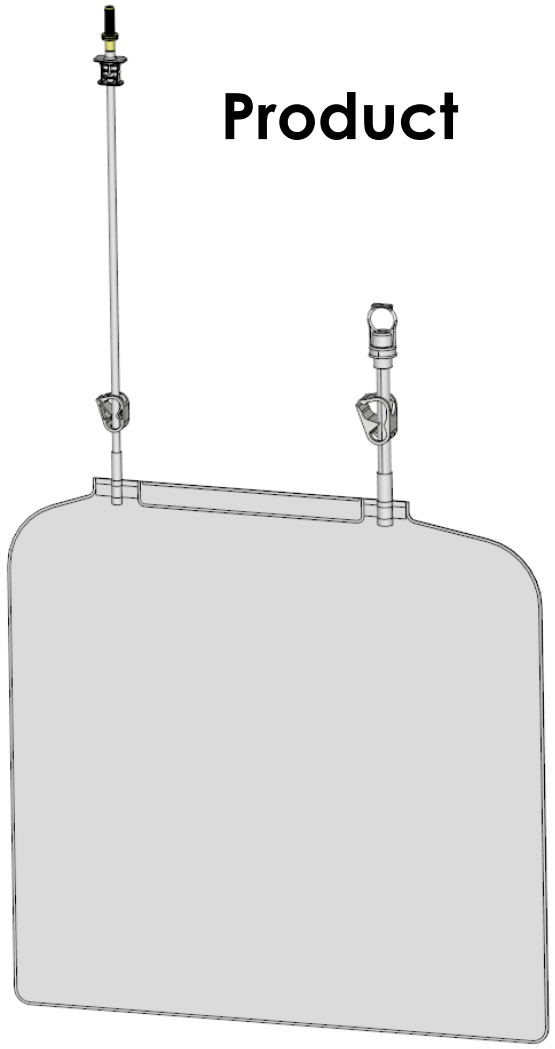
ANALYSIS & OPTIMIZATION

3D MODELING AND CAD IMPORT THE PRODUCTS



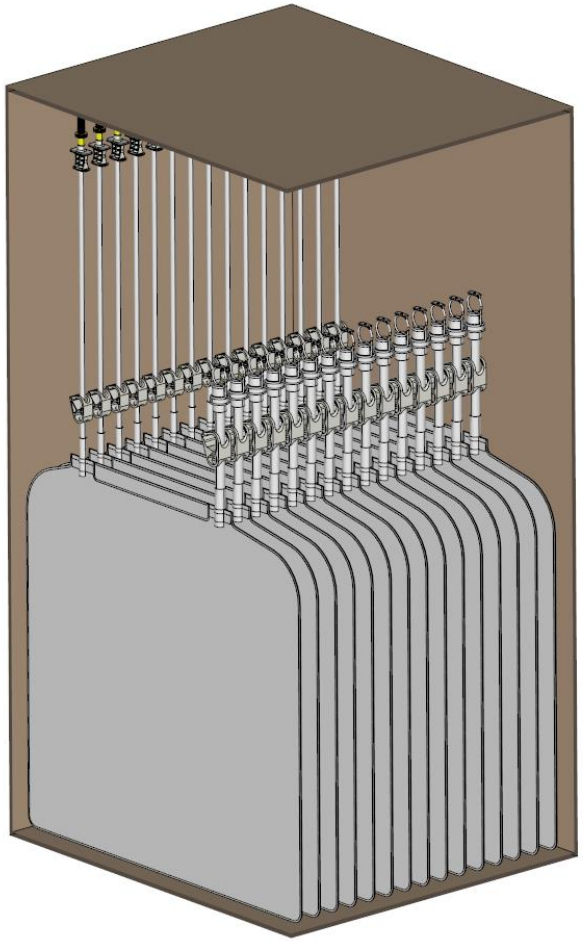
3D MODELING

Product

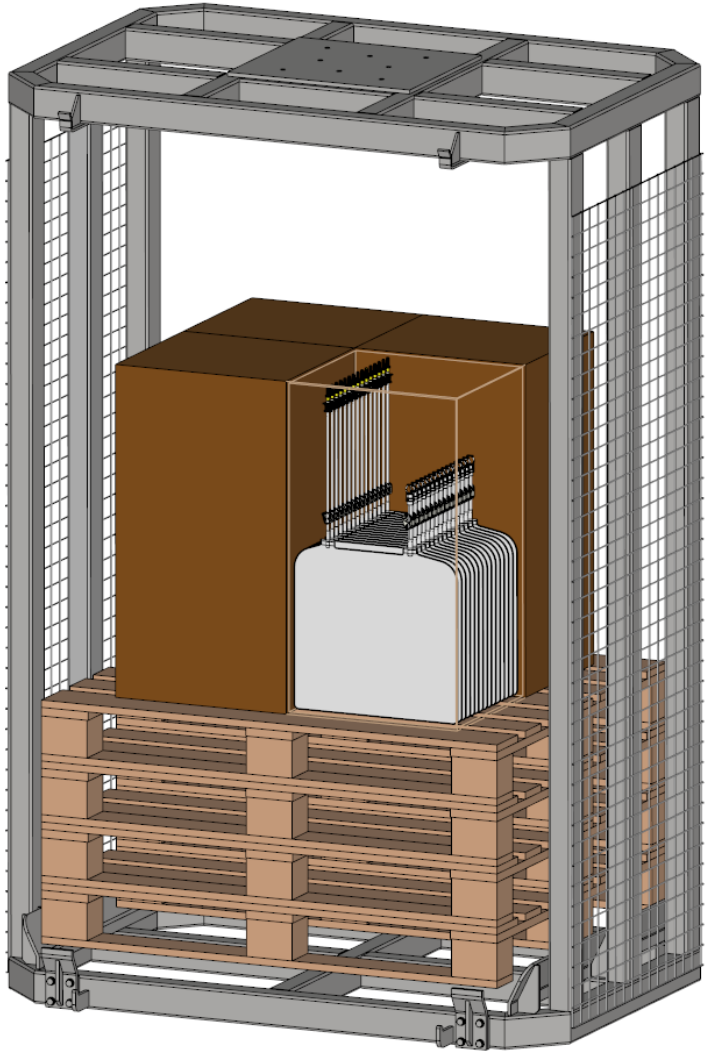


Drain bag
(CAD file)

Products on a cardboard box



Products on a carrier



3D MODELING

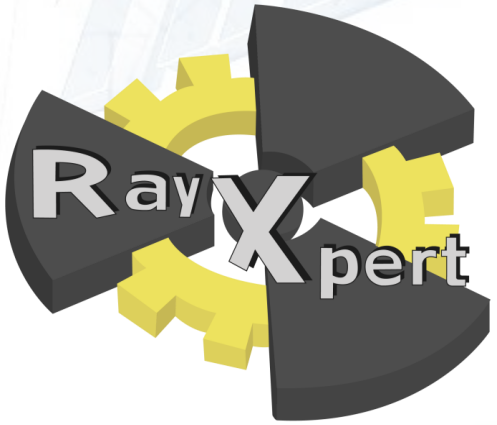
SOURCE DEFINITION

3D MAPPING

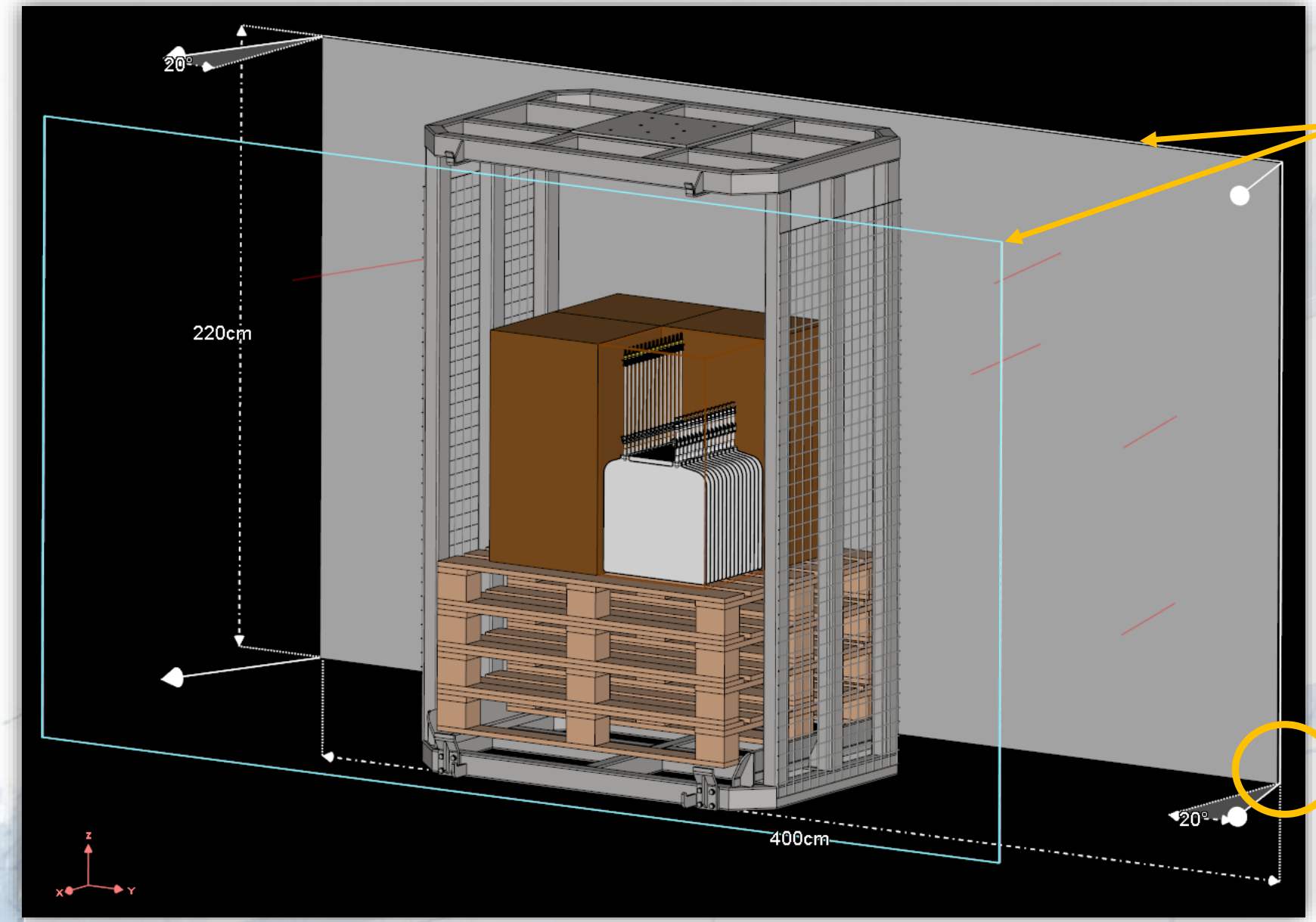
VIRTUAL DOSIMETERS

ANALYSIS & OPTIMIZATION

BEAM SETUP

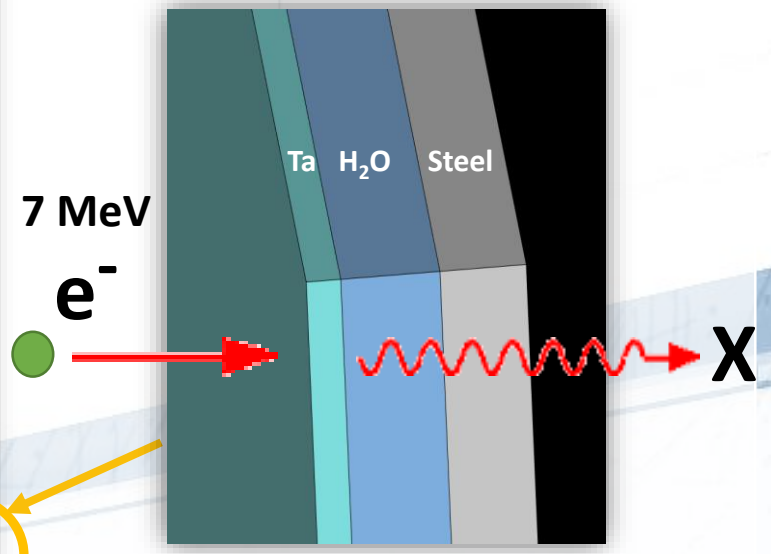


SOURCE DEFINITION



Settings :

- Double sided irradiation
- 2 × 7 MeV Ebeam
- 2 × Ta conversion target



Simplified converter

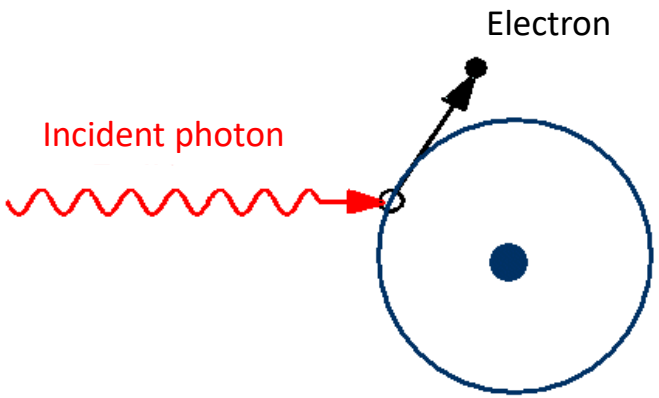
SOURCE DEFINITION

Physics involved

Simulate statistically the interactions between radiations and matter

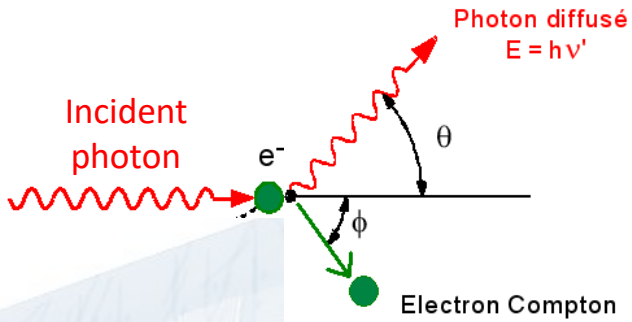
Photons

Photoelectric effect



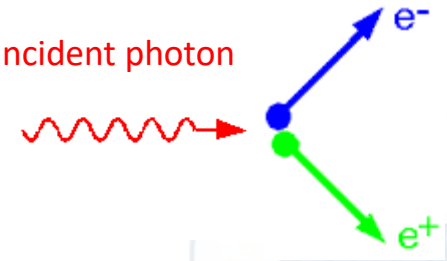
Predominance
E < 50 keV

Compton diffusion



Predominance
0.05 MeV < E < 20 MeV

Pair production



Predominance
E > 20 MeV

Secondary electron production → Dose deposition

3D MODELING

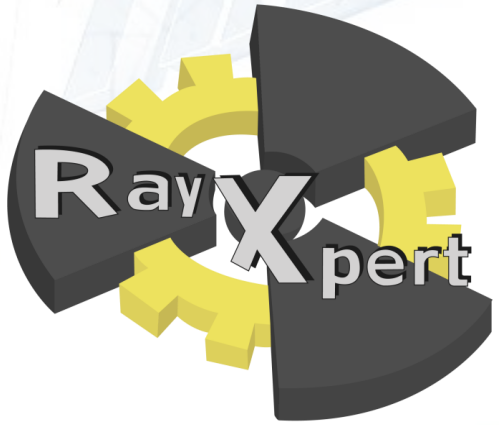
SOURCE DEFINITION

3D MAPPING

VIRTUAL DOSIMETERS

ANALYSIS & OPTIMIZATION

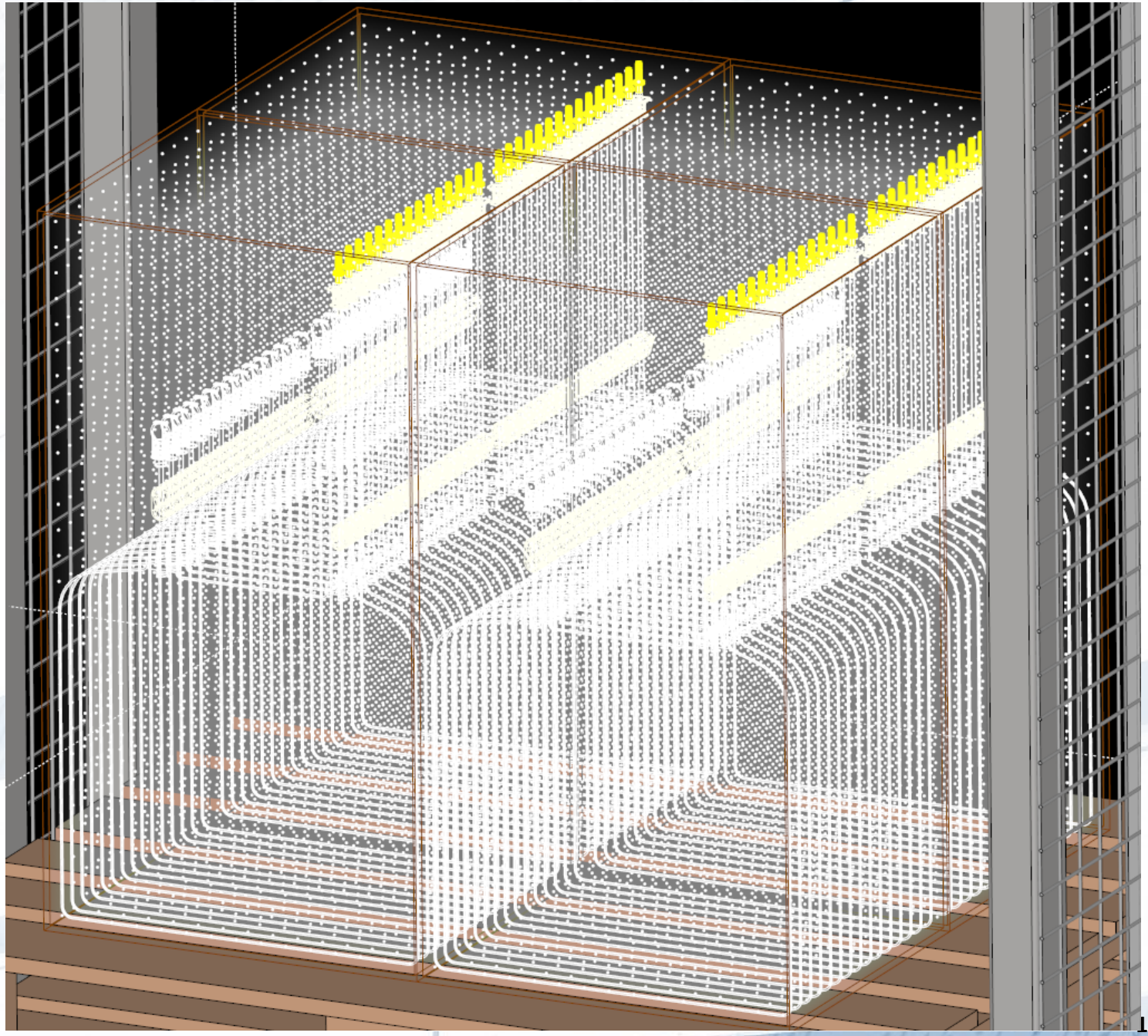
3D MAPPING INSIDE THE PRODUCTS



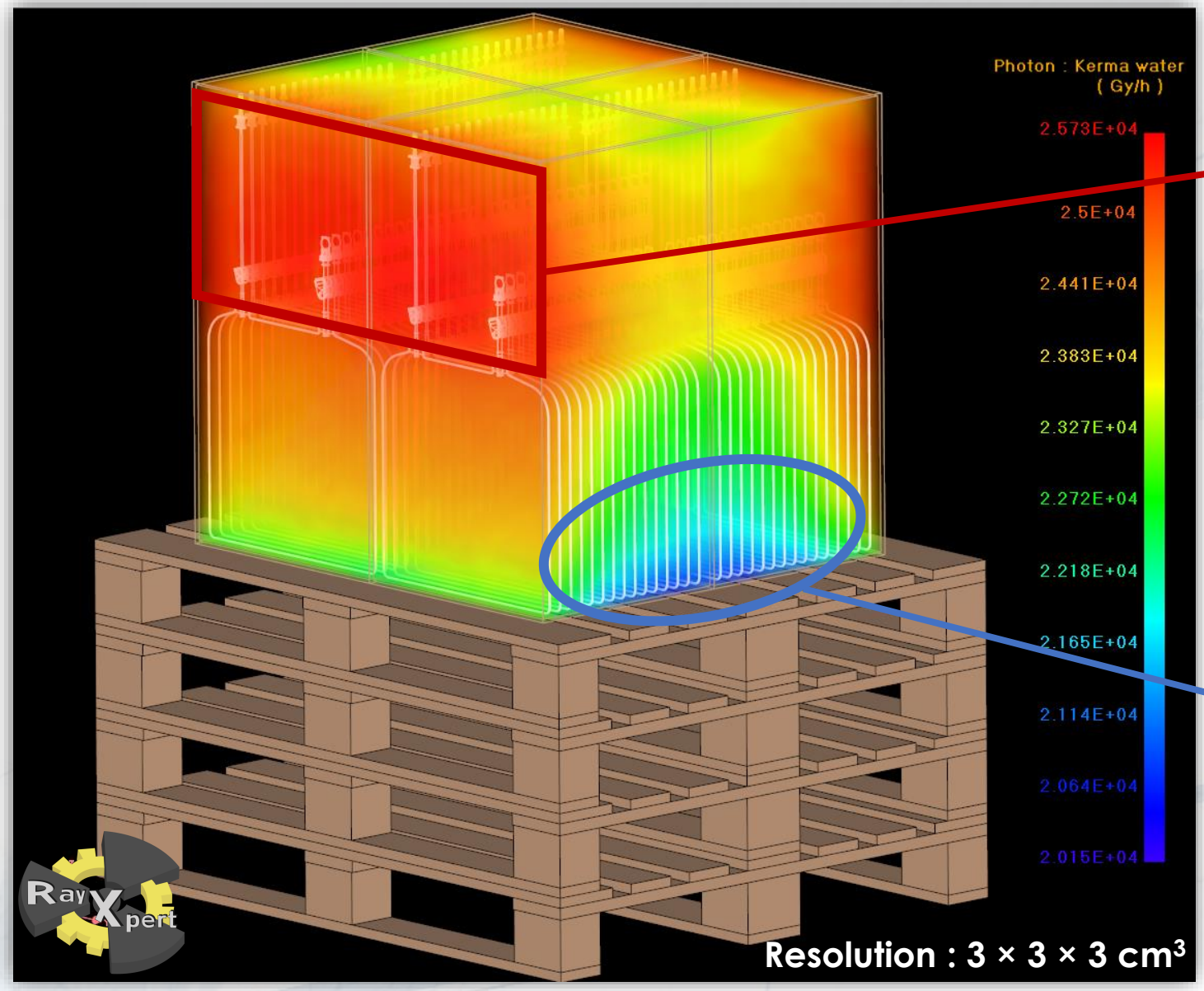
CALCULATION OUTPUT

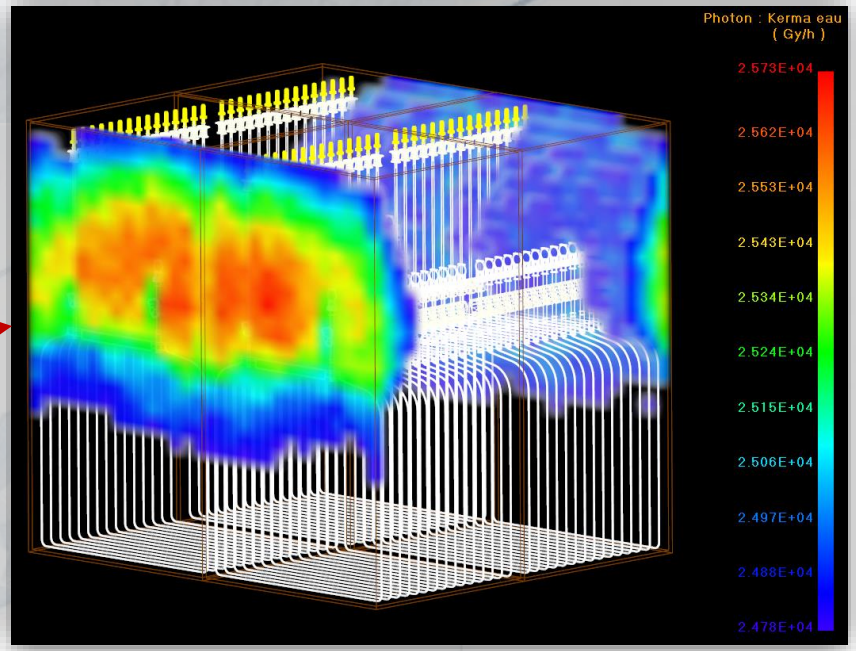
3D mapping

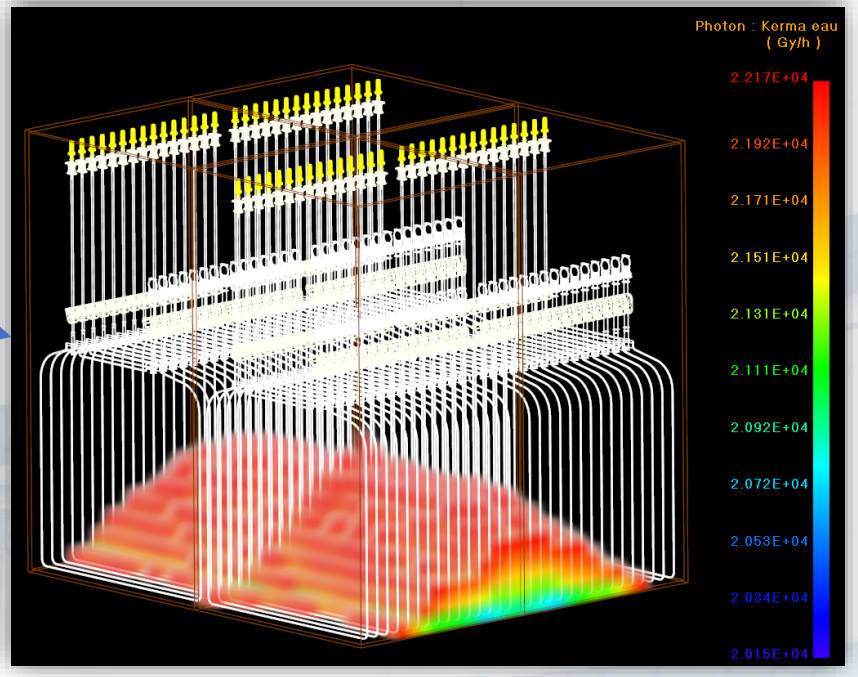
- Kerma water calculated
- Results in Gy/h
- Virtual mapping in all cardboard boxes
- **22 680** voxels in total



RESULTS WITH A 3D MAPPING







3D MODELING

SOURCE DEFINITION

3D MAPPING

VIRTUAL DOSIMETERS

ANALYSIS & OPTIMIZATION

VIRTUAL DOSE MAPPING

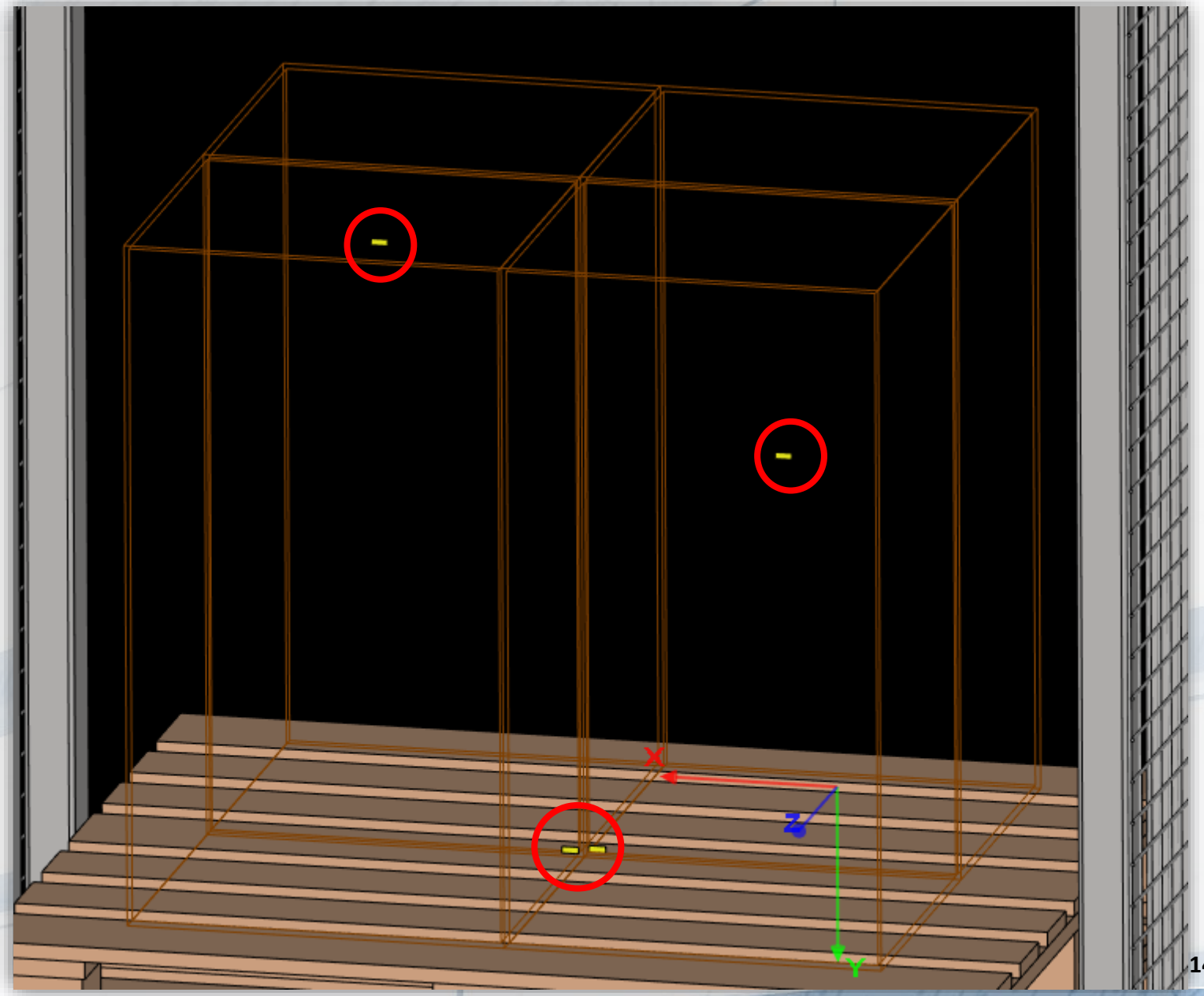
CALCULATION OUTPUT

Detectors

- Absorbed dose calculated
- Results in Gy/h
- Full of water with

$$\rho = 1.0\ g/cm^3$$

- Dimensions :
  - 2 cm × 0.8 cm × 125 µm
  - *similar to a CTA film*



RESULTS IN THE DETECTORS

Detectors	Absorbed dose in water (kGy/h)*		Kerma water (kGy/h)*	
	Value	Standard deviation	Value	Standard deviation
Maximum location	22.2	6.4%	25.2	0.5%
Minimum location	19.2	6.8%	20.2	0.5%

- Quantities available for the dose calculation
- Dosimeters can give both quantities (alanine, CTA etc.)
- Have to choose the quantity in your interest

**calculations for 1σ*

3D MODELING

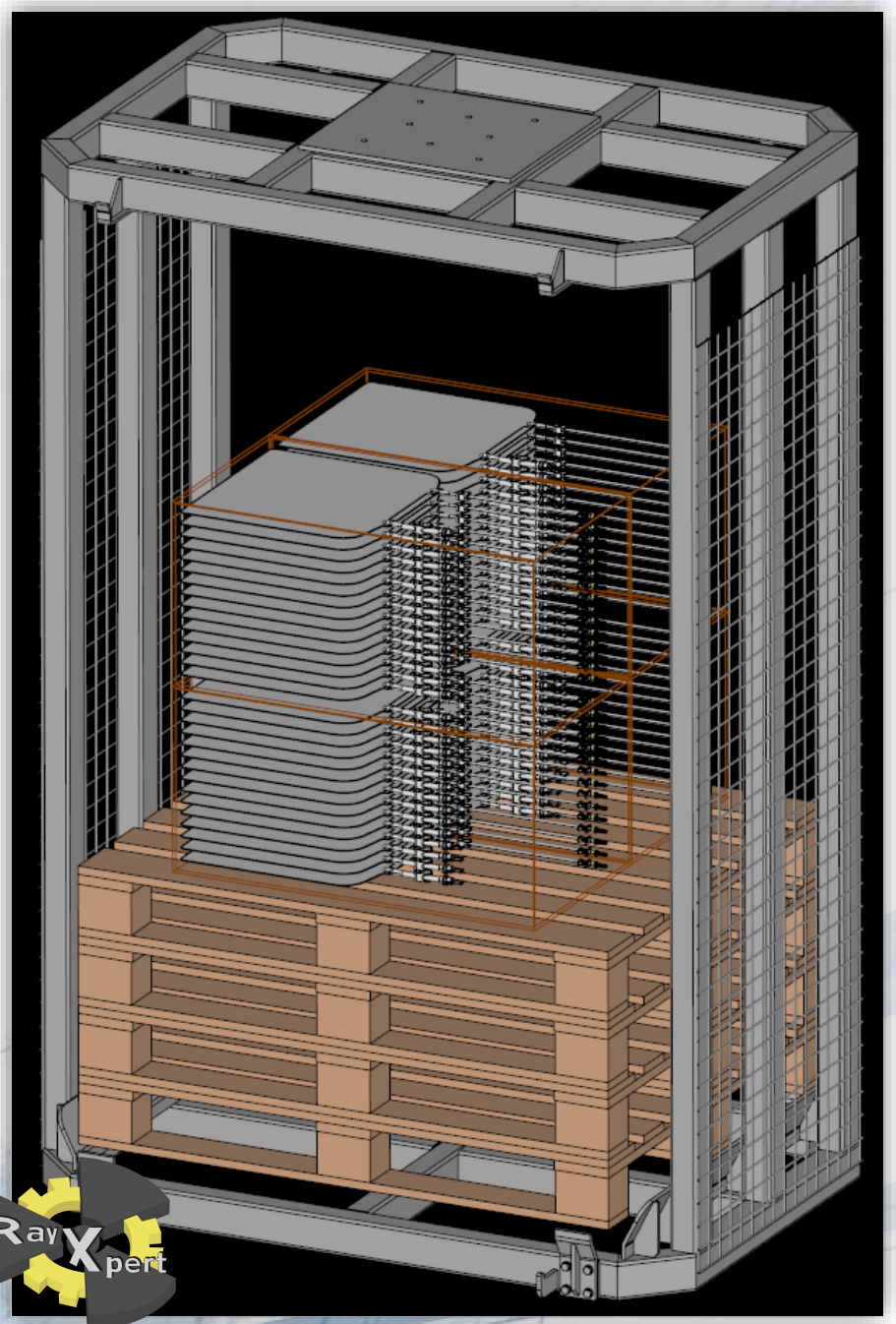
SOURCE DEFINITION

3D MAPPING

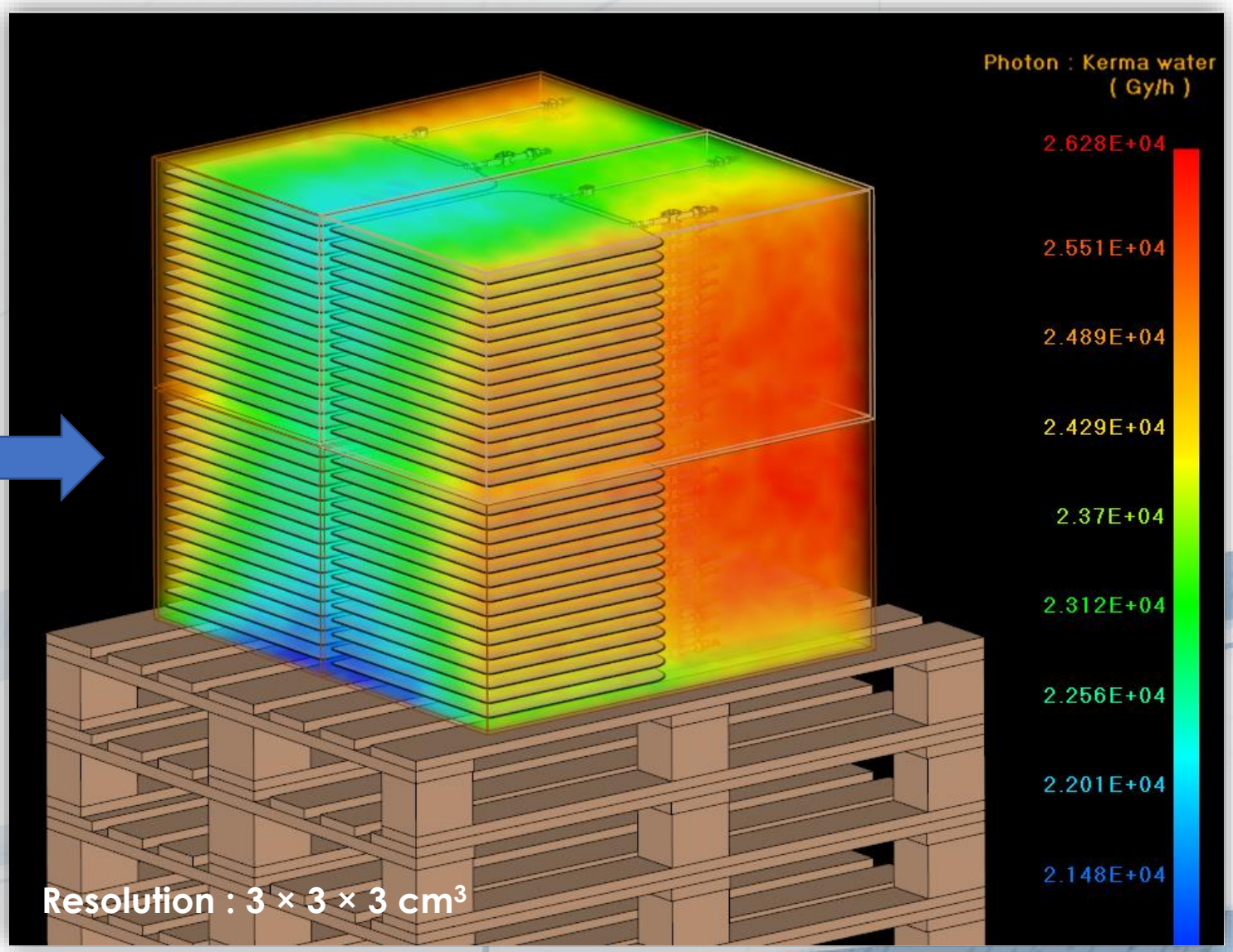
VIRTUAL DOSIMETERS

ANALYSIS & OPTIMIZATION

DIFFERENT CONFIGURATION

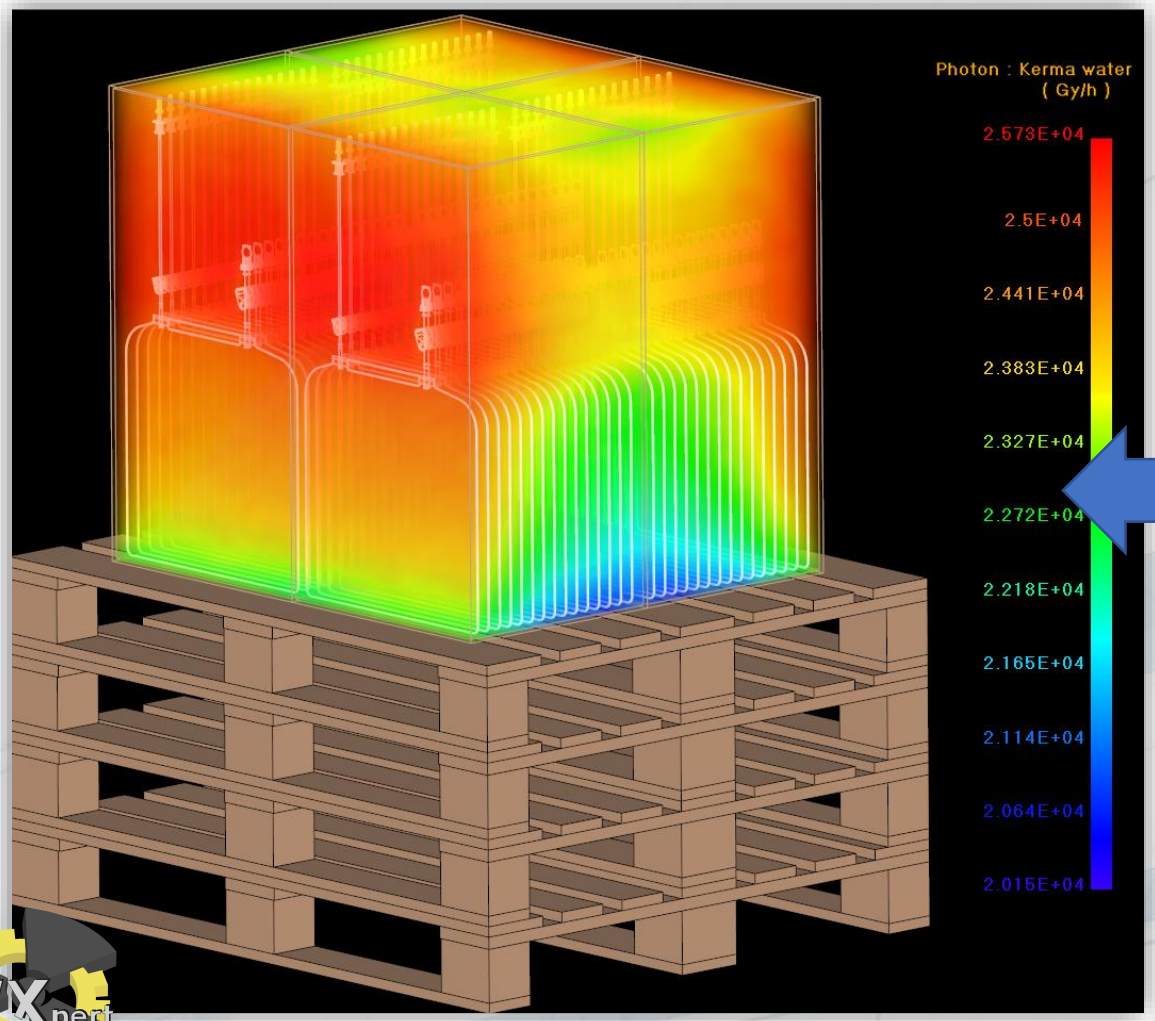


*Simulation **adaptability** and **responsiveness** allow easily to test different configuration of the product*

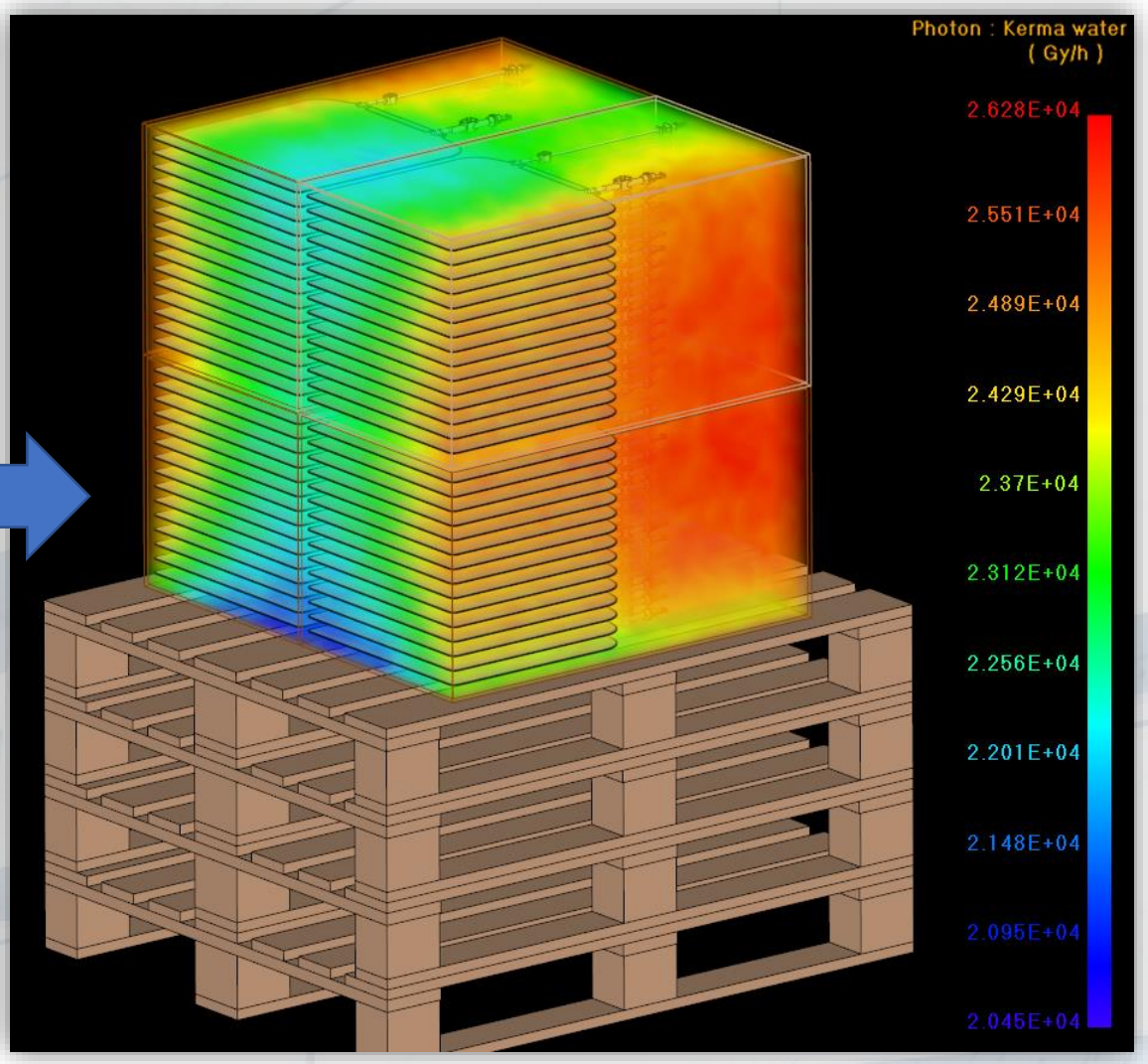


*Simulation **adaptability** and **responsiveness** allow easily to test different configuration of the product*

Vertical



Horizontal



CONCLUSION

As a complementary tool to dosimetry and OQ/PQ dose mappings, simulation results help to optimize the dosimetry and the process

- ✓ precise localisation of minimum and maximum dose areas
- ✓ precise localisation of dosimeters, reduce dosimeters number
- ✓ irradiation duration : dose rate information
- ✓ test different configurations
- ✓ optimise the process
- ✓ reduce human errors

And at the end, Monte Carlo simulation helps to

- ✓ **Reduce cost of dosimetry**
- ✓ **Increase confidence in dose mapping**
- ✓ **Increase your efficiency (Quality/Qualification time)**

WHAT DO THE STANDARD SAY ?

For Medical device sterilization by radiation processing

11137-3:2017

→ **Calculation results should be verified with dose measurements**

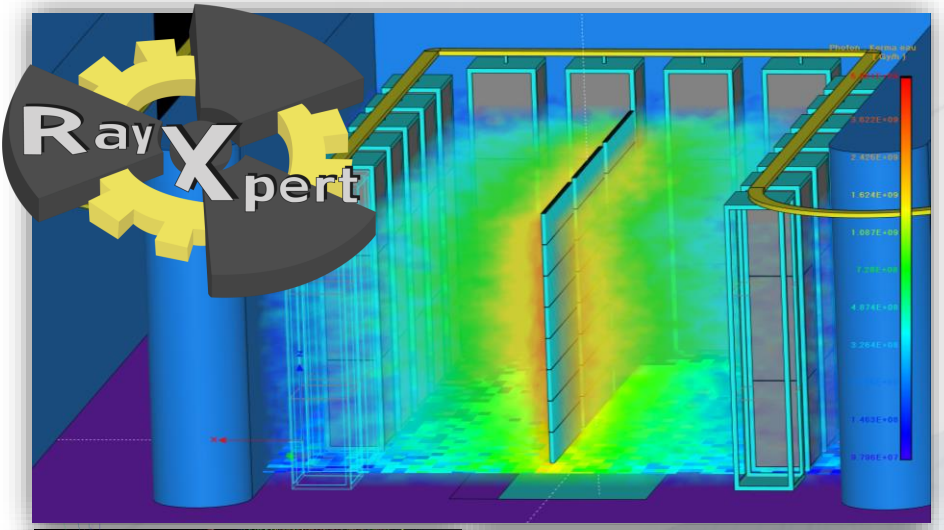
✓ **The combination of Monte Carlo simulation and dose mapping can <u>significantly reduce</u> the number of dose mappings required**

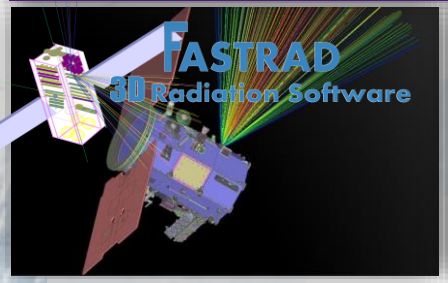
- ✓ Can be used to ensure that you use enough dosimeters place on the minimum and maximum dose zones
- ✓ Can be used to choose the right type of dosimeter
- ✓ Can be used for interpolating measured results to determine the dose distribution for non-homogeneous products
- ✓ Can confirm that dose specifications can be met
- ✓ Can help you to determine the optimum irradiation radiation scenario

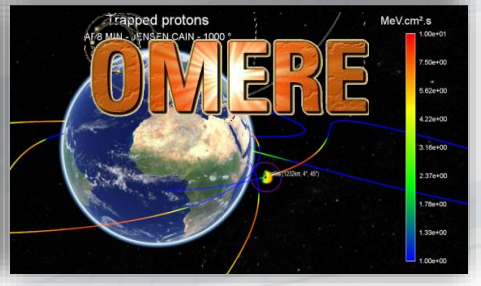
TRAD Tests & Radiations

Since 1994, we have been helping our customers with their projects involving radiation issues. From Space to Earth, with simulation & radiation processing

SOFTWARES EDITORS & ENGENIERING







RADIATION RESISTANCE TESTS

RAD HARD ELECTRICAL COMPONENT

R2 COTS

For more information :

rayxpert.com
trad.fr
r2cots.com
fastrad.net

INDUSTRIAL
SOLUTIONS

Damien PRIEELS – Product Manager (Research)

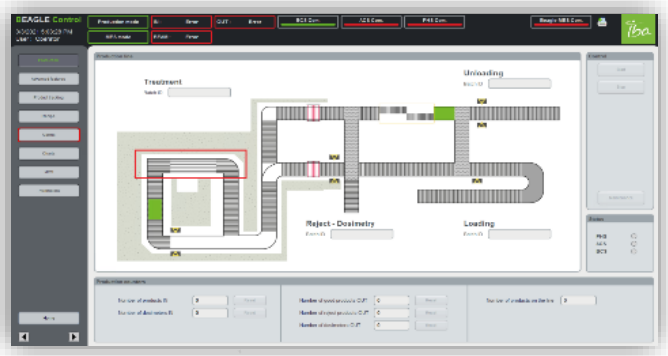
IBA & TRAD decided to enter into a long-term partnership

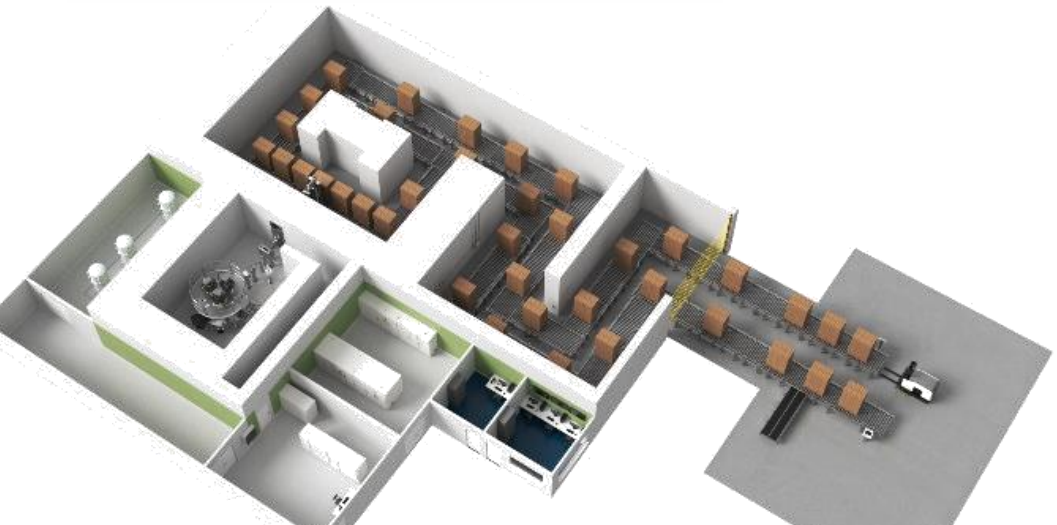
INDUSTRIAL SOLUTIONS

- ✓ Active in radiation processing market & shared vision
- ✓ Strong complementarities
- ✓ Potential for synergies

TRAD Tests & radiations

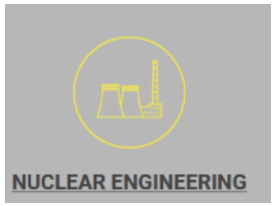
RayXpert

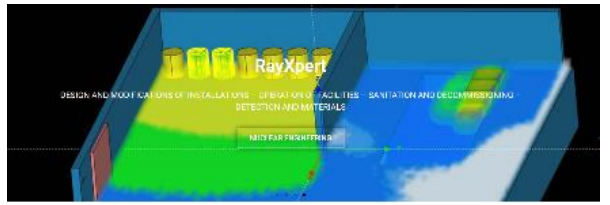


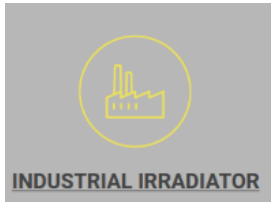


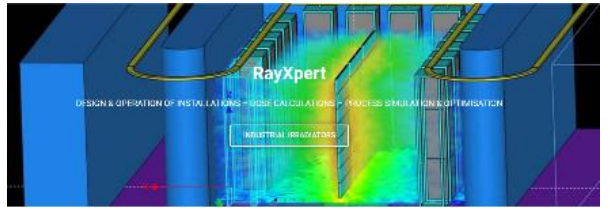
Sept. 21st, 2021

- Marketing
- Sales
- R&D









Specific module of RayXpert dedicated to radiation processing

We believe Monte Carlo will help significantly OQ & PQ

INDUSTRIAL SOLUTIONS

Design | Product qualification (PQ) | Production

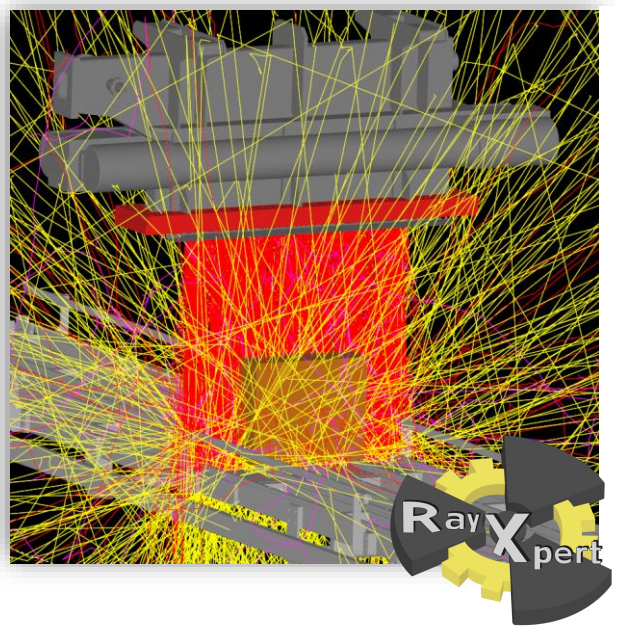
Product Design → Sterilisation selection → Packaging Design → Dose mapping / Shelf life → Manufacturing → Sterilization → ...

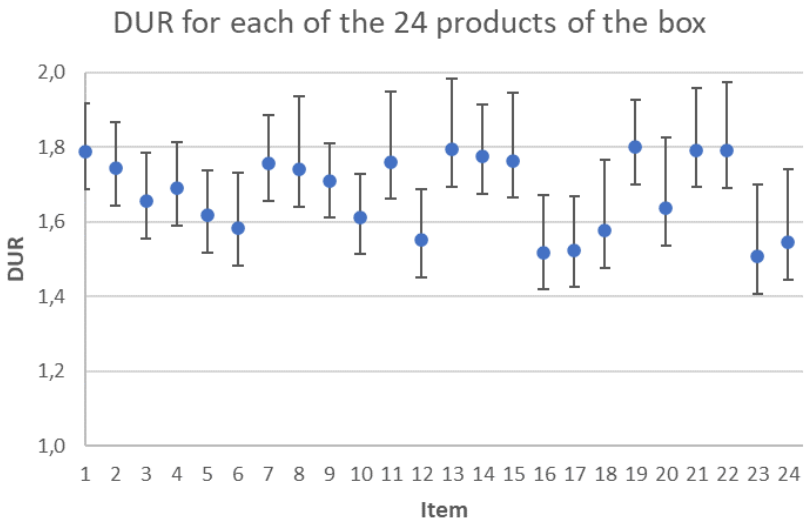
- Sterilization options?
- Feasibility?
- Shelf life?
- ...

Monte Carlo simulation

Monte Carlo simulation

Monte Carlo simulation





We are looking for candidate(s) to participate to a MC study

Objective & Content

Demonstrate MC simulations help OQ & PQ
and therefore support the transition from EO & gamma to EB & XR

- ❑ Selection of appropriate center(s) & product(s)
- ❑ Optimization of Qualification process AND/OR product packaging + MC study with RayXpert®
- ❑ Dose mapping
- ❑ Evaluation of benefits for the stakeholder

www.iba-industrial.com

www.trad.fr

www.aerial-crt.com

Application & Benefits

You are interested
&
You have process/product(s) you want to qualify

Apply @
www.iba-industrial.com/form/call-applications
(places are limited)

- ❑ Access to RayXpert
- ❑ Qualification of your process or product(s)
- ❑ Support from TRAD, IBA & Aerial

Thank you for your attention

Application form to participate to the POC

www.iba-industrial.com/form/call-applications

Contact: damien.prieels@iba-group.com
antoine.ghilardi@trad.fr